

IN THE IPEA/EP

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Title of Invention ANTENNA CORE MATERIAL FOR USE IN MWD RESISTIVITY MEASUREMENTS AND NMR MEASUREMENTS		
Applicant: Baker Hughes Incorporated		Article 19 amendments
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AMENDMENTS UNDER ARTICLE 19

Attention: Authorized Officer
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Dear Sir or Madam:

The Applicant requests that the amendments in the attached pages be entered. New pages 19-27 replace original pages 19-27

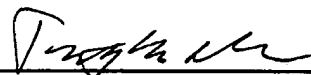
Comments on claim amendments

In claim 1, line 12, the word "non-ferritic" has been added.

In claim 1, lines 12-13 the words "at least one of (I) high internal magnetostrictive damping, and, (II)" have been deleted.

In claim 10, line 12, the word "non-ferritic" has been added.

In claim 10, lines 12-13 the words "at least one of (I) high internal magnetostrictive damping, and, (II)" have been deleted.


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- 1 1. A nuclear magnetic resonance (NMR) logging apparatus for use in a
2 borehole for determining properties of an earth formation surrounding the
3 borehole, the apparatus comprising:
 - 4 (a) a magnet for inducing a static magnetic field in a region of interest in
5 the earth formation;
 - 6 (b) a transmitting antenna assembly for inducing a radio frequency
7 magnetic field within said region of interest and producing signals
8 from materials in the region of interest; and
 - 9 (c) a receiving antenna assembly for detecting said signals from said
10 region of interest;
- 11 wherein at least one of the antenna assemblies includes at least one magnetic
12 core formed from a non-ferritic material having low magnetostriction.
13
- 1 2. The NMR logging apparatus of claim 1 wherein said material has a
2 high internal damping and further comprises a powdered soft magnetic
3 material.
4
- 1 3. The NMR logging apparatus of claim 2 wherein the powdered soft magnetic
2 material is non-conductive and has a maximum grain size to
3 substantially reduce intragranular power loss at a frequency of said radio
4 frequency magnetic field.
5
- 1 4. The NMR logging apparatus of claim 2 wherein the powdered soft
2 magnetic material has a maximum grain size less than half a wavelength of an
3 acoustic wave having a frequency of said radio frequency magnetic field.
4
- 1 5. The NMR logging apparatus of claim 1 wherein said material has a
2 high internal damping and further has a large area within a hysteresis loop
3 associated with magnetostrictive deformation of the material.
4
- 1 6. The NMR logging apparatus of claim 2 wherein said at least one antenna

- 2 core further comprises a non-conductive bonding agent having substantial
3 acoustic decoupling between grains.
4
- 1 7. The NMR logging apparatus of claim 1 wherein said logging apparatus is
2 adapted to be conveyed on one of (i) a wireline, and, (ii) a drilling tubular.
3
- 1 8. The NMR logging apparatus of claim 1 wherein said material has a low
2 magnetostriction and comprises an amorphous metal.
3
- 1 9. The NMR logging apparatus of claim 1 wherein the transmitting antenna
2 assembly and the receiving antenna assembly are the same.
3
- 1 10. A method of determining properties of an earth formation surrounding a
2 borehole, the method comprising:
3 (a) using a magnet on a nuclear magnetic resonance (NMR) logging
4 apparatus conveyed in the borehole for inducing a static magnetic field
5 in a region of interest in the earth formation;
6 (b) using a transmitting antenna assembly for inducing a radio frequency
7 magnetic field within said region of interest and producing signals
8 from materials in the region of interest; and
9 (c) using a receiving antenna assembly for detecting said signals from said
10 region of interest;
11 the method further comprising using a core for at least one of the antenna
12 assemblies formed from a non ferritic material having low magnetostriction.
13
- 1 11. The method of claim 10 wherein said material has a high internal damping,
2 the method further comprising using a powdered soft magnetic material as
3 said material with high internal damping.
4
- 1 12. The method of claim 11 further comprising selecting the powdered soft
2 magnetic material to be substantially non-conductive and having a maximum

- 3 grain size to substantially reduce intragranular power loss at a frequency of
4 said radio frequency magnetic field.
5
- 1 13. The method of claim 11 further comprising selecting the powdered soft
2 magnetic material as having a maximum grain size less than half a
3 wavelength of an acoustic wave having a frequency of said radio frequency
4 magnetic field.
5
- 1 14. The method of claim 10 wherein said material has high internal damping, the
2 method further comprising selecting said material as having a large area
3 within a hysteresis loop associated with magnetostrictive deformation of the
4 material.
5
- 1 15. The method of claim 11 further comprising using in said at least one antenna
2 core a non-conductive bonding agent having substantial acoustic decoupling
3 between grains.
4
- 1 16. The method of claim 10 further comprising conveying said NMR logging
2 apparatus into said borehole on one of (i) a wireline, and, (ii) a drilling
3 tubular.
4
- 1 17. The method of claim 10 wherein said material has a low magnetostriction, the
2 method further comprising selecting an amorphous metal for use as said
3 material.
4
- 1 18. The method of claim 10 further comprising using the same antenna for the
2 transmitting antenna and the receiving antenna.
3
- 1 19. An apparatus for evaluating electrical properties of an earth formation
2 surrounding a borehole, the apparatus comprising:
3 (a) a transmitting antenna assembly for conveying a radio frequency

- 4 electromagnetic field into said earth formation; and
5 (b) a receiving antenna assembly for receiving a signal resulting from
6 interaction of said electromagnetic field with said earth formation;
7 wherein at least one of the antenna assemblies includes at least one of: (I) a
8 magnetic core formed from a material having high internal magnetostrictive
9 damping, and, (II) low magnetostriction.
10
- 1 20. The apparatus of claim 19 wherein said material has a high internal damping
2 and further comprises a powdered soft magnetic material.
3
- 1 21. The apparatus of claim 20 wherein the powdered soft magnetic material is
2 non-conductive and has a maximum grain size to substantially reduce
3 intragranular power loss at a frequency of said radio frequency magnetic field.
4
- 1 22. The apparatus of claim 20 wherein the powdered soft magnetic material has a
2 maximum grain size less than half a wavelength of an acoustic wave having a
3 frequency of said radio frequency magnetic field.
4
- 1 23. The apparatus of claim 19 wherein said material has a high internal damping
2 and further has a large area within a hysteresis loop associated with
3 magnetostrictive deformation of the material.
4
- 1 24. The apparatus of claim 20 wherein said at least one antenna core further
2 comprises a non-conductive bonding agent having substantial acoustic
3 decoupling between grains.
4
- 1 25. The apparatus of claim 19 wherein said apparatus is adapted to be conveyed
2 on one of (i) a wireline, and, (ii) a drilling tubular.
3
- 1 26. The apparatus of claim 19 wherein said material has a low magnetostriction
2 and comprises an amorphous metal.

- 3
- 1 27. A method of determining a resistivity parameter of an earth formation
2 surrounding a borehole, the method comprising:
- 3 (a) using a transmitting antenna assembly on a tool conveyed in said
4 borehole for transmitting a radio frequency electromagnetic field into
5 said earth formation;
- 6 (b) using a receiving antenna assembly for receiving a signal resulting
7 from interaction of said electromagnetic field with said earth
8 formation;
- 9 (c) using a core for at least one of the antenna assemblies for enhancing
10 the received signals, said core formed from a material having at least
11 one of (I) high internal magnetostrictive damping, and, (II) low
12 magnetostriction.
- 13
- 1 28. The method of claim 27 wherein said material has a high internal damping,
2 the method further comprising using a powdered soft magnetic material as
3 said material with high internal damping.
- 4
- 1 29. The method of claim 28 further comprising selecting the powdered soft
2 magnetic material to be substantially non-conductive and having a maximum
3 grain size to substantially reduce intragranular power loss at a frequency of
4 said radio frequency magnetic field.
- 5
- 1 30. The method of claim 28 further comprising selecting the powdered soft
2 magnetic material as having a maximum grain size less than half a wavelength
3 of an acoustic wave having a frequency of said radio frequency magnetic
4 field.
- 5
- 1 31. The method of claim 27 wherein said material has high internal damping, the
2 method further comprising selecting said material as having a large area
3 within a hysteresis loop associated with magnetostrictive deformation of the

- 4 material.
5
- 1 32. The method of claim 28 further comprising using in said at least one antenna
2 core a non-conductive bonding agent having substantial acoustic decoupling
3 between grains.
4
- 1 33. The method of claim 27 wherein said material has a low magnetostriction, the
2 method further comprising selecting an amorphous metal for use as said
3 material.
4
- 1 34. The method of claim 27 wherein said tool is conveyed into the borehole on
2 one of (i) a wireline, and, (ii) a drilling tubular.
3
- 1 35. An apparatus for evaluating electrical properties of an earth formation
2 surrounding a borehole, the apparatus comprising:
3 (a) a transmitting antenna assembly for conveying an electromagnetic
4 field into said earth formation; and
5 (b) a receiving antenna assembly for receiving a signal resulting from
6 interaction of said electromagnetic field with said earth formation;
7 wherein at least one of said antenna assemblies includes at least one magnetic
8 core formed from a non-ferritic powdered soft magnetic material having high
9 saturation flux density and a non-conductive bonding agent, said magnetic
10 core having a magnetic permeability μ_m less than 500 and wherein said
11 saturation flux density is greater than about 0.4 T.
12
- 1 36. The apparatus of claim 35, wherein the magnetic core further comprising
2 dimensions which are related to the direction of an RF magnetic field
3 produced by the transmitter coil and to the magnetic permeability of the
4 powdered soft magnetic material.
5
- 1 37. The apparatus of claim 35 wherein the powdered soft magnetic material is

- 2 conductive and has a maximum grain size to substantially prevent
3 intragranular power loss of said transmitted electromagnetic signal.
4
- 1 38. The apparatus of claim 35 wherein an effective demagnetizing factor of the
2 magnetic core in a direction of the radio frequency magnetic field
3 substantially exceeds the inverse magnetic permeability of the powdered soft
4 magnetic material.
5
- 1 39. The apparatus of claim 36, wherein the core has an effective permeability, μ ,
2 less than 5, as defined by a first equation,
3
$$\mu = 1 + (\mu_m - 1) / ((\mu_m - 1) \cdot D + 1),$$

4 wherein D, the demagnetizing factor can be estimated from an elliptic
5 equivalent of the cross-section of the core, as defined by a second equation,
6 $D = S_x / (S_x + S_y)$,
7 wherein S_x and S_y represent the elliptic equivalent dimensions in horizontal
8 and vertical dimensions respectively, in a plane the core.
9
- 1 40. The apparatus as defined in claim 35 wherein the powdered soft magnetic
2 material possesses a maximum magnetic permeability given a predetermined
3 maximum RF antenna power loss.
4
- 1 41. The apparatus of claim 35 wherein said flux density is greater than that of a
2 magnetic core consisting primarily of ferrite.
3
- 1 42. The apparatus of claim 35 wherein the magnetic core further comprises
2 relative dimensions that are related to the direction of the RF magnetic field
3 and to the magnetic permeability of the powdered soft magnetic material.
4
- 1 43. A method of making measurements of a parameter of interest of an earth
2 formation comprising:
3 (a) conveying a logging tool into a borehole in said earth formation;

- 4 (b) using a transmitter antenna assembly on the logging tool for
 5 conveying an electromagnetic field into the earth formation;
 6 (c) using a receiver antenna assembly for detecting signals resulting from
 7 interaction of said electromagnetic field with said earth formation, and
 8 (d) including in at least one of the antenna assemblies a magnetic core
 9 formed from a non-ferritic powdered soft magnetic material having
 10 high saturation flux density and a non-conductive bonding agent, said
 11 magnetic core having a magnetic permeability μ_m less than 500 and a
 12 saturation flux density greater than about 0.4T.

13
 1 44. The method of claim 43 further comprising selecting dimensions for the
 2 magnetic core which are related to the direction of the magnetic field and to
 3 the magnetic permeability of the powdered soft magnetic material.

4
 1 45. The method of claim 43 further comprising selecting relative dimensions for
 2 the magnetic core which are related to the direction of the magnetic field and
 3 to the magnetic permeability of the powdered soft magnetic material

4
 1 46. The method of claim 43 wherein the powdered soft magnetic material is
 2 conductive, the method further comprising selecting a maximum grain size for
 3 the soft magnetic material to substantially prevent intragranular power loss of
 4 said radio frequency magnetic field.

5
 1 47. The method of claim 43 wherein an effective demagnetizing factor of the
 2 magnetic core in the direction of the magnetic field substantially exceeds the
 3 inverse magnetic permeability of the powdered soft magnetic material.

4
 1 48. The method of claim 47, wherein the core has an effective permeability, μ ,
 2 less than 5, as defined by a first equation,

$$\mu = 1 + (\mu_m - 1) / ((\mu_m - 1) \cdot D + 1),$$

3
 4 wherein D, the demagnetizing factor can be estimated from an elliptic